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R.I. Press and Ye.M.Shandalov

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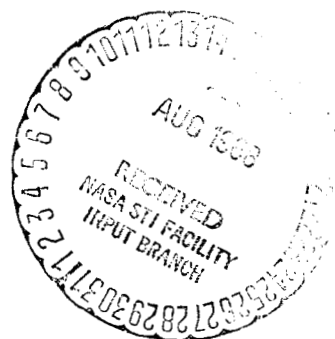
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ABSTRACT: This article gives the description of a plasma anemometer which uses a high-frequency ac discharge to measure rapidly varying processes, particularly the rapid velocity pulsations of an airflow. The principles of operation and the block and circuit diagrams of the device are examined, and its superiority over a glow-discharge anemometer is demonstrated. Tests performed with the device showed that in the deflection of the flow toward the discharge axis, there appears in the discharge current a constant component that is proportional to the angle of deflection. This effect, attributed to the deformation of the ion space charge, makes it possible to measure the angular velocity component of the flow.

In the solution of many experimental problems, e.g., in the analysis of the operation of jet technology facilities (pneumatic studies), it is necessary to measure pulsations in the velocity of an airflow.

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It is possible in some cases to use a thermoanemometer or an anemometer which employs a direct current glow-discharge. For measuring rapidly alternating processes, however, difficulties begin to show up in the design and performance of the thermoanemometer. The glow-discharge anemometer also has several disadvantages, such as the intensive burning-out of the electrodes, the instability of the current in the discharge, and so on [1]. The conversion to a discharge with a high-frequency ac power source has enabled us to essentially eliminate the shortcomings of the glow-discharge anemometer.

The newly designed plasma anemometer contains two identical blocks which make it possible to make simultaneous measurements in different locations (Fig. 1).

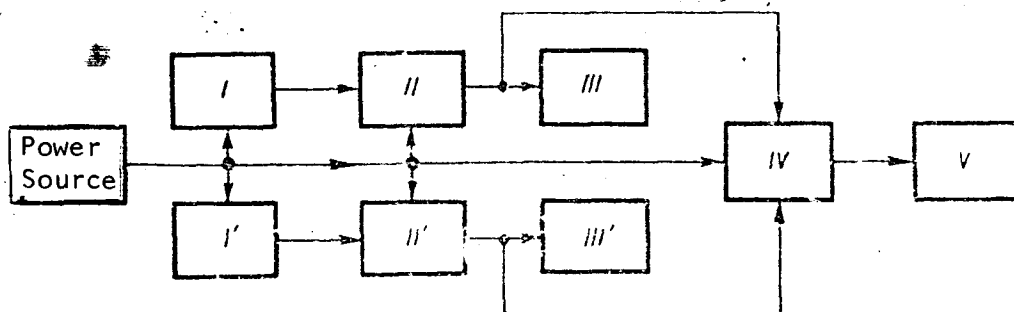


Figure 1. Diagram of Device

¹Numbers in the margin indicate pagination in the foreign text.

The first block consists of master generator I, power amplifier II, and discharger III. The second block consists of the analogous components I', II' and III'. Comparison operator IV, which consists of a differential amplifier with a bridge output, and indicator apparatus V are common to both blocks. Either a dial or a loop or electronic oscillograph, in conjunction with an additional detector apparatus, may be used as the latter.

Dischargers III and III' are set up at the output of the power amplifier and a high-frequency discharge is created between their electrodes. The electrodes of the discharger are made of two platinum electrodes with a \emptyset of 0.5 millimeters, which are placed in the current being studied.

The frequency of the power source of the apparatus is selected such that the electrons do not completely pass the discharge gap in the time of a half period of the power source voltage. In this case the electrons accumulate in the discharge gap, which greatly intensifies the discharge, significantly increasing its stability even up to rather high velocities of the gas stream. The upper limit of the frequency of the power source voltage to the discharge will be that frequency at which the energy losses to emission become quite great and the delivery of the high-frequency energy to the dischargers is impeded. We therefore selected a frequency of 5 Mhz for the power supply of the apparatus.

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The apparatus operates in the following manner (Fig.]). The oscillations produced in the anode region of the high-frequency generator, which is represented by pentode V_1 , arrive at the grid of the power amplifier, which is represented by pentode V_2 . The load of the power amplifier is the high-frequency circuit, whose inductance is represented by the primary coil of the step-up high-frequency transformer and the secondary coil of which leads to the discharger.

At a definite distance between the electrodes of the discharger (0.1-1.0 millimeters), which is established with micrometric screw, a high-frequency discharge, which forms a low-temperature plasma, is developed between the electrodes. The ions located in the discharge gap reproduce all the pulsations of the gas stream, accordingly changing the signal at the output coil of the transformer.

One of the outputs of the secondary coil, by passing through inductance L_5 , provides for the formation of the input signal for the differential amplifier, which is represented by dual triode V_5 . The signal from the analogous stage of the other block goes into the other half of V_5 and insures reduced distortions resulting from interference occurring in both channels in opposite phasing. The alternating component of the desired signal, which characterizes the pulsations in the velocity of the stream under investigation, is produced at the output of the circuit.

When the circuits are matches, the critical value is the voltage on the GU-50 control grid, which is selected experimentally in such a way as to insure a discharge with stable glow without overheating the electrodes.

Since it is practically impossible to obtain a symmetrical differential output from one contour because of the lack of matching of the output branches, which is caused by the redistribution of the current of the high-frequency energy as a function of the loads on these branches, two independent channels are used.

When it is necessary to operate on one channel of the device, potentiometer R provides a zero at the output of the comparison circuit.

The manufacturing of the discharger [2] involved electrodes with small dimensions, careful welding of the electrodes to firm mountings, quality insulation of the electrodes from the chassis of the discharger, manufacturing of the mounts from heat-conducting materials, use of electrodes of spherical shape, and also stipulated the proper selection of the material of the electrodes.

The distance between the electrodes determines the sensitivity of the plasma anemometer and is selected in accordance with the required range of measurement of the velocities with consideration of the fact that as the velocity of the stream under investigation increases then the gap between the electrodes must decrease. Otherwise the "blow-out" of the discharge is possible.

By considering the physics of the operation of the device, it may be considered that changes in the voltage on the electrodes are caused:

(1) By mechanical deformation of the electrodes, caused by the pressure of the stream or by its heating effect on the burned out electrodes as a consequence of the discharge;

(2) By the effect of atmospheric cooling on the thermionic properties of the electrodes;

(3) By the effect of the pressure of the surrounding medium;

(4) By the leaking of ions from the discharged gas [3].

If the measurement probe is well constructed, the last of the causes enumerated above will predominate. The space charge of the ions during high-frequency discharge is distinguished by low mobility because of the relatively high inertia of the ions and variations in the discharge are caused primarily by the influence of the airflow, which significantly distorts the picture of the distribution of the space charge by forming a glowing tail behind the discharge.

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Also, in addition to the causes enumerated above, there is yet another mechanism which causes variations in the resistance of the discharged gas.

When the pressure of the output is high at a distance pd between the electrodes, the predominating mechanism of the electron losses is electron adhesion, i.e., the formation of negative ions in this manner [4].

In the case at hand, where the apparatus operates at atmospheric pressure and the distance between the electrodes is rather great, the value of pd may be regarded as high. Therefore it may be assumed with sufficient basis that the negative ions formed as a result of electron adhesion will be blown away from the discharge gap by the airflow. The phenomenon of electron diffusion resulting from high values of pd is disregarded.

The balance equation of particles, upon consideration of the airflow as directed toward the axis of the discharger, has the form

$$\frac{\partial n}{\partial t} = (v_i - v_r)n + D\Delta n + \mu V \nabla n,$$

where V is the velocity of the gas stream, n is the concentration of the electrons; v_i is the frequency of ionization; v_r is the frequency of recombination; D is the diffusion coefficient; μ is a dimensionless value characterizing the construction of the discharger.

As follows from the solution of the balance equation of particles [1], the dependence of voltage applied to the discharger on the velocity of the airflow has a quadratic character. Nevertheless, it depends substantially on the distance between the electrodes of the measurement probe.

During visual observations of the discharge, it is possible to see the typical picture of the flow of a high-frequency discharge in air at atmospheric pressure. This picture is similar to that which is seen while observing glow-discharge under the very same conditions [5].

When the distance between the electrodes $d \approx 0.2$ millimeters, a discharge is observed which is accompanied by bright blue near-electrode coronas. In the presence of an airflow these coronas move freely along the electrodes. As the distance between the electrodes is reduced, starting with $d = 0.6$ millimeters, a new portion of the discharge, less bright and narrower than the near electrode corona, appears. As the distance is increased further, up to 1.4 - 1.7 millimeters, there occurs a discharge band with a diameter of 0.8 - 0.9 millimeters [5]. The length of the band changes as the distance between the electrodes varies, while the dimensions of the near-electrode coronas remain about the same.

It was noted that for deviations in the direction of the current from normal to the axis of the discharge, a constant component appears in the flow of the discharge which is proportional to the angle of inclination. This is attributed to deformations of the ionic space charge [1]. This makes it possible to measure the magnitude of the angular components of the velocity of the flow being investigated.

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